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A POWER QUALITY NEWSLETTER

Point of View

The popularity of decentralized energy sources, or distributed resources, is likely to transform the electrical environment in the United States. Most of these decentralized energy sources—including microturbines, fuel cells, and photovoltaics—make use of new electronic switching technologies to convert electrical energy to a usable form. While these electronics usually optimize the energy conversion function of the systems, they also inject all kinds of harmonic and interharmonic currents into the electrical network as a by-product. Standards for connecting and monitoring these devices are needed because practical problems are already being encountered around the world.

Recently, I had the opportunity to review the results of some European research efforts into power quality. In Belgium, measurements of harmonic currents showed that the value of the 2nd and 4th harmonics—less common "even" harmonics, which are considered to be more undesirable than the "odd" number variety—substantially exceeded the emission limits of existing International Electrotechnical Commission standards. The investigators concluded that as these harmonic levels increased, so would the malfunctioning of

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Power Quality: A Growing Concern in the Plastics Industry

by Bob van Brederode, PhD

Every day, processing plants are injection-molding, blow-molding, roto-molding, thermoforming, and extruding plastic materials to make products found in every facet of our lives. Plastics are commonly used in medical, automotive, appliance, agricultural, household, packaging, telecommunications, and computer applications, among others. These applications will only increase as engineering developments make plastic materials lighter and stronger, and their processing capabilities faster, thinner, and more consistent.

Processing equipment consumes a great deal of electricity as plastic material is dried, melted, and pressed into final form. In the United States alone, the industry consumes 14 billion kWh of electricity annually. During manufacturing, plastics are sensitive to extended exposure to heat. In-spec products depend on consistent equipment operation at optimum conditions. If not handled carefully, the plastic can degrade and product properties can suffer. Product flaws—such as warpage of injection-molded auto or computer parts, or blisters on thermoformed trays—result in scrapped material until processing conditions stabilize.

Burgeoning Industry

Per capita consumption of plastic materials has soared since the 1970s, as plastics replace conventional metal, glass, and wood products. To put the industry's growth in perspective, U.S. manufacturing shipments of plastic products have grown about 4% annually over the past 25 years. In the same period, shipments by all other U.S. manufacturers increased just over 1% per year. Today, plastic products rank fourth among the top U.S. manufacturing industry groups—only behind motor vehicles, petroleum refining, and electrical components and accessories.

As the plastics industry has grown, so has the use of programmable logic controllers, instrument power supplies, photo eyes, and other sophisticated electronic equipment in the processing environment. And as manufacturing tolerances grow increasingly tighter, the impacts of voltage sags and other power disturbances take on greater significance. These impacts are of concern to all types of plastics processors, and are most notable and costly where a continuous process is involved, such as plastic extrusion.

Narrow Parameters

In the plastic pipe manufacturing process, incoming plant power quality is of critical importance. To produce plastic pipe, the heated

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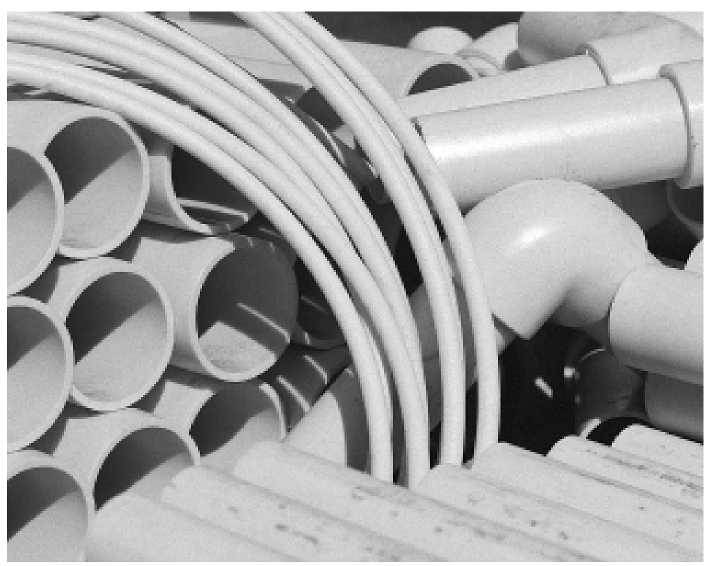

Between 1991 and 1996, the shipment value of plastic products manufactured in the United States grew by 55%, reaching $274 billion.

Allegheny Cuts Sags at Plastics Plants

by Fred Frank

Today's plastics plants are highly modern facilities that use continuous, automated processes incorporating adjustable speed drives (ASDs), electrical contactor switches, and programmable logic controllers (PLCs). To stay on-line, these sensitive processes and equipment require premium power quality. Take the case of two plastics processing facilities served by Allegheny Power from the same distribution feeder.

One plant produces polystyrene—the material used in styrofoam cups and other insulating products. The plant processes the material in railroad car volumes, and sells the product for a few cents a pound. Polystyrene processing creates heat, and because the material is highly volatile, requires constant cooling to avoid the dangers of fire and explosion. A voltage sag can open contacts on the starters of cooling water pumps, signaling the process controller to shut the pumps down. When this occurs, the manufacturer must use chemicals to cool the polystyrene instead. This results in ruined product, and can lead to two to three days of cleanup time. It can also create a "sold-out" condition, so that even when running at full capacity, the plant cannot fulfill customer orders.

The second plant processes specialty plastic, which is used in car fenders, telephones, keyboards, and other such goods. This plant produces relatively small quantities of high-value material, selling at about $20 per pound. Rather than needing cooling, specialty plastic must be heated during processing. A voltage sag can trip extruder dc drives and process heaters. When this happens, the plastic material hardens, and then must be chipped or hammered out of the extruder. Equipment damage becomes another of the processor's concerns.


Courtesy of Allegheny Power

Plastics processors consume more than 14 billion kWh of electricity every year.

These processing plants, which are located adjacent to each other in eastern Ohio, are served from a nearby 138-kV transmission network substation. Due to the sensitivity of the plants' production processes, we constructed two independent and parallel 13.8-kV distribution feeder circuits from the substation, using resistive grounded neutrals to 20 ohms. The feeders, which were built on separate wooden poles, cross through two miles of open field. As a result, they are not exposed to two common causes of faults: contact by trees and motor vehicles.

We told the customers that this feeder arrangement would reduce the possibility of power quality-related downtime to about once every seven years. But in 1996 the otherwise independent plants simultaneously shut down three times due to voltage sags on our system—and then another three times in 1997. Production losses varied in quantity because of differences between the two plant processes. Even so, the estimated cost for both customers was $100,000 per occurrence. Understandably, the customers wanted us to take action to remedy the problem.

Focused Investigation

We initially suspected lightning as the cause of the faults. However, upon investigation we found that either feeder, when interrupted by a direct lightning strike, would clear and reclose properly within 10 seconds, keeping the other circuit in service. Further examination revealed that a fault on one feeder would cause voltage on the other feeder to sag to about 65% of nominal. This brought operations to a halt at both plants.

We looked into two possible solutions: 1) installing overhead shield wire protection on both feeders, at a cost of around $60,000; and 2) installing surge arresters on every other pole of both feeders, about $18,000. We considered arrester installation the better of the solutions, both technically and economically, and presented this approach to the customers for their consideration. They were somewhat guarded in their enthusiasm, however, having had little experience with the use and effectiveness of arresters in this application.

At this point, we called in EPRI for a presentation on the effectiveness of arresters in providing lightning protection. Following this presentation, the customers elected to accept our proposal for arrester installation, under the stipulations that arresters be placed on every pole for added protection and that the ground resistance be lowered to five ohms. The total estimated cost to Allegheny for this solution was $40,000.

We then brought in engineers from EPRI PEAC Corporation to lead a discussion with plant personnel on their production processes, and to develop ride-through techniques for reducing the impacts of voltage sags. One suggested technique was to set the ASDs in the plants to restart automatically following sags of less than one second. Also recommended was the use of coil hold-in devices to keep contactors closed during sags of less than one second. Preliminary testing would need to be done, however, to ensure that the drives and processes would not be damaged by these measures.

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Duke Molds Plastics Industry Partnership

by Jeff Dougherty

Products made from plastics and polymers come in all shapes, sizes, colors, and capacities. We're using plastics, for example, when we type at a computer keyboard, take the trash out, or tap the alarm clock in the morning. Other polymers like rubber and polyester also have countless applications.

In the United States, shipments of plastic products have more than tripled in the last 25 years. As the plastics industry has grown, so has its reliance on computer-controlled and electronic manufacturing equipment. And as those of us in the electric power industry know, such technologies are highly sensitive to even minor disturbances in the electric supply.

At Duke Power, with more than 350 of our industrial customers involved in plastics processing, we have a strong interest in the sustained livelihood of the industry. It has been our experience that power quality-related shutdowns of plastics manufacturing processes—many of which are continuous in nature—can cost as much as $50,000 per event.

In the power quality arena, we place special emphasis on effectively responding to customer inquiries, and on being proactive in our research and development efforts. One such effort led to the development of a sag generator, which can be used to create voltage sags on the power supply and determine the weak links within a customer's production process.

We also use the EPRI Power Quality Database to document customer inquiries involving power quality. In 1997, an analysis of the database showed that power quality concerns were growing within the plastics industry. Having successfully targeted power quality issues and solutions for the textiles industry in the early 1990s, we believed that plastics processing would benefit from a similar endeavor.

Bringing Stakeholders Together

In July 1997, Duke Power cosponsored a local "Industry Issues" meeting with the North Carolina-based Polymers Extension Program (PEP). This meeting helped bring to light the growing challenges around power quality in the plastics industry, as well as equipment and environmental compatibility issues. While industry participants were well aware of how power disturbances impacted their productivity, we found they were not familiar with efforts to address these problems. One outcome of the meeting was an understanding that all stakeholders—plastics processors, equipment manufacturers, energy providers, consultants, and trade organizations—needed to be involved in a concerted effort to address power quality and equipment sensitivity issues.

In October 1997, Duke Power, PEP, the Society of the Plastics Industry (SPI), and EPRI cosponsored a Power Quality Workshop that drew attendees from around the country. Feedback from this workshop called for further study of equipment sensitivities, case studies to document power quality problems and solutions, and more information on cost-effective mitigation devices. Based on this feedback, in 1998 Duke Power initiated a Tailored Collaboration project with EPRI focusing on the plastics industry. The objectives were to test process equipment and determine which power quality problems are unique to the industry.

Courtesy of Duke Power

The continuous process of cable jacket extrusion will shut down in response to a voltage sag.

The project targeted five of the major plastics manufacturing processes: 1) plastic pipe extrusion, 2) injection molding, 3) blown thin-film processing, 4) cable jacket extrusion, and 5) thick-film thermoforming. We tested each of these processes, using the sag generator to identify which components were most sensitive to voltage sags and interruptions. In most cases, we found cost-effective solutions that would "harden" the process to voltage sags, thereby reducing equipment downtime and increasing productivity.

CommScope Inc., a manufacturer of communication cables, was one of the customers who joined with us in this project. CommScope's plant in Claremont, North Carolina, was experiencing an average of 15 voltage sags a year. These disturbances were causing one or more extrusion lines to shut down—and costing many thousands of dollars per event.

To support plant load additions, modifications were made to the incoming electrical service and, after sag generator testing, to the extrusion equipment itself. Equipment modifications included the installation of a constant voltage transformer on the controls of the equipment. As a result, the number of events that shut down equipment at the plant is now estimated to be roughly five per year. In fact, a recent thunderstorm caused problems at a nearby CommScope sister-plant, but not at the Claremont plant.

Providing Outreach

We have been presenting results like these at various industry meetings, including EPRI's PQA'99 and conferences sponsored by the Institute of Electrical and Electronics Engineers and the Society of Plastics Engineers. Our intent is to help educate the

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Standards Update

by Tom Key

Even though the processes of the plastics and polymers industry are often upset by electrical disturbances, industry-specific standards currently do not exist to help engineers measure and cope with such disturbances. The plastics industry encompasses a diverse group of companies, many of which are small and often specialize in a particular process and product. These companies are represented by organizations such as the Society of the Plastics Industry (SPI) (*http://www.socplas.org*) and Society of Plastics Engineers (*http://www.4spe.org*).

Standards for the industry come from organizations like the American Society for Testing and Materials, and the American National Standards Institute. However, the standards from these organizations do not include much on power delivery or power quality. The Institute of Electrical and Electronics Engineers (IEEE) has a functioning Rubber and Plastics Industry Committee within its Industrial Applications Society. However, few electrical standards are developed in this IEEE forum, and the membership best represents the more power-intensive rubber industry.

NFPA Standard 79

For electric power and related safety issues, the plastics industry has aligned itself with the special requirements developed for machine tools in Article 670 of the National Electrical Code (NEC), and in the larger National Fire Protection Association (NFPA) Standard 79. Neither of these are recent standards. NEC Article 670 originally came from the metalworking, machine-tool industry in 1943, and NFPA added the separate Standard 79 in 1961.

In the mid-1970s, as the plastics industry was taking form, SPI members began working within NFPA to expand Standard 79 to specifically include plastics machinery in the 1980 edition. Today, NFPA 79—"Electrical Standard for Industrial Machinery, 1997 Edition"—has become an important power quality reference for machine tools and related processing equipment, ranging from metalworking computer numerical control machines to semiconductor fabrication tools and plastics injection-molding equipment.

Since its inception, NFPA 79 has been tightly coupled with related NEC articles. It references a number of other standards, including those from IEEE, International Electrotechnical Commission, Underwriters Laboratories, and National Electrical Manufacturers Association. A section on general operating conditions, while not directly referring to power quality, details expectations for the electric supply, from voltage distortions to sags. It states that under the indicated electric supply conditions, "electrical equipment shall be designed to operate correctly under full load as well as no load . . . unless otherwise specified by the user." This section of NFPA 79 provides a baseline immunity requirement for machine tools.

Immunity Levels for Commercial and Industrial Equipment

Questions on Machine and Process Power Quality (from IEEE 1346)	Preferred Response from Original Equipment Manufacturer (from IEEE 1346)	Specified Voltage Excursions for Correct Operation (from NFPA 79)
How much, and for how long, can supply voltage sag before equipment malfunctions?	Provides graph with magnitude (100% to 0% of nominal) and duration. Also includes maximum unbalance and point-on-wave data.	Voltage sags to 80% of nominal up to one cycle (16.67 ms), with one second or more between successive sags.
What are steady-state voltage tolerances?	Specifies minimum operating range of ± 10%, with same range for all machine components.	Voltage magnitude 90% to 110% of nominal, and 3-phase unbalance to 2% (based on symmetrical components).
How long can zero voltage be tolerated?	Provides machine and process operating limits, and provision for orderly shutdown beyond limits. Recommends conducting tests to confirm.	Voltage interruptions up to three occurrences at any point in waveform, with one second or more between successive interruptions.
What is the machine's transient voltage withstand capability?	Provides coordinated suppression adequate for surge of 1.2/50 μS at 2 kV to 6 kV, with grounding sufficient for a frequency range of 3 kHz to 1 GHz.	Voltage impulses not to exceed 1.5 ms in duration, rise/fall time of 0.5 μS and 500 μS, and a peak of 200% of rated rms voltage.
How much voltage distortion can the equipment tolerate?	Specifies equipment tolerances for voltage total harmonic distortion (to 10%), crest factor (to 2.5 times Vrms), and notching (to declared level given in volt-microseconds).	Voltage harmonics not to exceed 10% line-to-line for rms sum of 2^{nd} through 5^{th}, and an additional 2% of line-to-line for rms sum of 6^{th} through 30^{th}.
What frequency variation limits are allowed?	No guideline given.	Frequency 99% to 101% of rated, continuously; and 98% to 102%, short-time.

Taken together, IEEE 1346 and NFPA 79 help define the gap between equipment capabilities and the likely electrical environment.

The 60-page NFPA standard also covers other aspects of power, control, and safety for industrial machine tools, including control diagrams, wiring practices, and protection and grounding. It includes proper operation of emergency-stop, hold-in, and interlock circuits, which are often involved with power quality-related upsets to industrial processes. More information on the standard, as well as NFPA's on-line catalog, can be found at *http://www.nfpa.org/Codes* on the Web.

IEEE Standard 1346

Another standard—equally relevant but little known so far to the plastics industry—is the recent IEEE Standard 1346-1998, "Recommended Practice for Electric Power System Compatibility With Electronic Process Equipment." As noted in *Standards Update* last year (see *Signature*, Fall 1998, NL-111521), this standard addresses the compatibility of electric supply and industrial processes. It provides a common procedure for use by equipment manufacturers, end users, energy providers, and consultants in evaluating power and process incompatibilities.

This is one of the first IEEE power quality standards to provide a methodology for resolving incompatibilities. For example, IEEE 1346 shows that by overlaying a sag magnitude-duration chart from the power company with susceptibility limits from the process equipment manufacturer, users can predict potential incompatibilities and determine costs. This methodology promotes effective mitigation actions with supporting investment payback calculations.

The standard also provides a list of questions for specifiers to pose to suppliers before purchasing industrial process equipment. It is interesting to compare the IEEE 1346 preferred responses from original equipment manufacturers with the specified operating limits of NFPA 79. IEEE 1346 promotes more detailed responses from the manufacturers, describing equipment electrical compatibility, while NFPA 79 specifies minimum compatibility levels. As the table shows, the two standards are complementary in reducing the compatibility gap, but they do not eliminate it.

Clearly, additional coordination between these standards will add to their value. In the meantime, IEEE 1346 and NFPA 79 can be used to support the notion that, while the electric supply should be less disturbing, industrial processes should also possess reasonable immunity. This is a refreshing concept for the power quality consulting and power conditioning business, which in the past has focused on fixing rather than preventing problems.

Now electrical engineers can use the methods from IEEE 1346 to predict occurrences and costs of incompatibility, while applying NFPA 79 to establish a minimum immunity level for equipment. Economic assessments can be made to show the best investment options for improving compatibility. Choices include the specification of more robust industrial equipment, selective application of power conditioning, and improvements to the building and incoming electric power systems. By applying the IEEE and NFPA standards, alternative corrective measures can be more effectively identified and implemented.

Energy Provider Role

The equipment specifiers and process engineers of the plastics industry are not as familiar with power quality as engineers in more power-intensive industries, such as petrochemicals or pulp and paper. They probably do not have experience with distribution power quality details—including those used in the development of IEEE 1346—and are more accustomed to specifying machine operation and installation using standards like NFPA 79. As their processes grow increasingly complex, they may be looking for assistance in determining the electric power requirements of their plants.

It is reasonable to expect that many plastics plants will need power quality assessments to support the design and specification of their processes. Energy providers, with their unique expertise in the area of power quality, can provide valuable assistance. By applying methods from IEEE 1346, energy providers can help plastics process engineers to

- evaluate the voltage sag susceptibility of critical process components,
- map expected sag events in the electrical environment,
- predict the number and extent of upsets, and
- recommend specifications for process electrical equipment.

This is a particularly good opportunity for energy providers to lend a hand in defining the electrical environment, and to help customers in the plastics and polymers industry translate electrical parameters into machine and related control specifications. At the same time, equipment manufacturers can take steps to improve equipment response to power disturbances. These proactive measures will lead to more profitable and satisfied customers. ■

Tom Key is vice president of technology at EPRI PEAC Corporation (*http://www.epri-peac.com*) in Nashville, Tennessee. This column serves as an open forum on power quality standards activities and developments. Please send your comments to *tkey@epri-peac.com*.

EPRI R&D Corner

In a targeted effort to improve the compatibility of plastics processing equipment with the electric power system, EPRI has launched the Power Quality Initiative for the Plastics and Polymers Industry. As a task of the System Compatibility Research Project at EPRI PEAC Corporation, the initiative builds on work introduced by Duke Power into power quality issues impacting the plastics industry. The utility initiated an industry-focused effort in 1998, when it set up an EPRI Tailored Collaboration project to characterize the power quality needs of various plastics processes (see *Duke Molds Plastics Industry Partnership* on page 3).

In the initiative, engineers from EPRI PEAC are working with plastics processors and equipment manufacturers to identify power quality problems within plastics plants and equipment designs. In some cases, equipment susceptibility testing is done in the field to allow more precise identification of process equipment sensitivities and to evaluate potential solutions. Industry technical and professional associations are also involved to facilitate the development of power quality standards.

Through industry workshops and conferences for end users, equipment manufacturers, and sponsoring energy providers, EPRI will share the knowledge gained from the power quality investigations and solution demonstrations. These meetings will also provide the impetus for development of performance specifications and compatibility standards. In this way, industry standards organizations can be influenced to work toward the goal of complete system compatibility.

By participating in the initiative, energy providers will gain valuable knowledge of the plastics industry, and will be armed with the latest power quality solutions. Bottom line, they will have the tools to expand their industrial business bases and enhance existing customer relationships, while helping customers improve their productivity and profitability.

For more information on the initiative, contact Brian Fortenbery at 423-974-8341 (*bfortenbery@epri-peac.com*). A plastics workshop will be held November 16-17, 1999, in Charlotte, North Carolina. For details, contact Marsha Grossman at 650-855-2899 (*mgrossma@epri.com*).

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extruder receives a pelletized compound from a hopper, and a screw heats the material and forces it through a die into cooling tanks. Once cooled, the hardened pipe is pulled down the line by a puller, where a saw cuts the pipe to specified lengths.

When incoming voltage sags, numerous extrusion lines can shut down all at once, breaking the continuous flow of plastic. This causes the entire process to be interrupted, and leaves operators scrambling to quickly restart and purge each of the lines. A delayed restart and purging can result in the hardening of material in the equipment and, ultimately, in a production nightmare. Extruder lines producing larger-diameter pipe can take several hours to return to optimal levels, and many tens of thousands of dollars can be lost.

This can be of serious consequence in an industry that is highly competitive. In terms of sheer numbers, there are more than 13,000 small-to medium-sized production facilities operating throughout the United States. Small shops that they are, plastics processors often have tight operating margins. Too much unscheduled downtime can quickly put the processor in a financial bind. Plus, products made during restart usually do not meet specification and wind up in the scrap pile. Beyond that, late or just-in-time deliveries can result in severe penalties and lost business.

Popular consumer products such as computer keyboards, monitor casings, and CD-ROMs are driving the growth of the plastics industry.

In an effort to take advantage of lower costs, some processors are moving their operations to Mexico and other offshore locations. Energy providers can play a key role in supporting the financial viability of plastics processing firms—while retaining customer load in their service areas—by mitigating the effects of power disturbances.

Needed Support

Production management and staff may grumble about power disturbances that shut down their equipment, diminish product quality, and cut into profits, but the majority of plastics processors have not taken steps to fix power quality problems. They wish the problems would go away, or simply choose to live with them, for two reasons:

1. ***Lack of knowledge***. Plastics processors, as well as the manufacturers of processing equipment, tend to be unaware of the multiplicity of causes of power quality problems, particularly within the boundaries of their own plants. Perhaps more significantly, they are not familiar with the role of their own equipment design or other available solutions to the problems.
2. ***Lack of resources***. Many of the smaller firms do not have the resources to hire extra help. They have only limited in-house capability to collect information about power quality, carry out needed upgrades to equipment and electrical supply, justify the cost of corrective action, and determine the payback on investment.

Service Opportunities

Excellent, detailed information is available within EPRI and the electric power industry that shows what plastics processors and processing equipment manufacturers can do to reduce the impacts of power disturbances. There are some relatively simple and inexpensive modifications that can be made to allow the equipment to withstand modest and reoccurring variations in the electric supply.

To help plastics processors reduce production losses caused by power disturbances, energy providers can

- help processors define their power environment and what problems to expect,
- furnish technical information on what needs to be done,
- pinpoint fixes in customer processes,
- develop industry-specific ride-through techniques,
- provide economic justification for making needed changes, and
- offer low-cost loans, as appropriate.

Equipment manufacturers have a role as well. They can make sure that their critical processing component parts are compatible with the electric supply and with each other.

There are several routes that energy providers can use to disseminate information to decision makers in the plastics industry. They can contact industry engineering and business associations, including the Society of Plastics Engineers, at 203-775-0471 (*http://www.4spe.org*); Society of the Plastics Industry (SPI), at 202-974-5200

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Other EPRI PEAC recommendations were to

- install uninterruptible power supplies on PLCs and sensors;
- place auto-restart equipment on high-intensity discharge lighting;
- review all control logic to eliminate circuit designs that could cause drop-out due to voltage sags;
- review circuits for unneeded redundant controls to minimize the possibility of voltage sag effect;
- provide auto-restart on compressed air and water pumps, as appropriate; and
- review startup procedures to bring operations back on-line more quickly.

Successful Implementation

In May 1998, we completed the installation of surge arresters on every pole of both 13.8-kV feeder circuits. Since then, there has not been a single interruption to the plants caused by lightning. The plants also implemented most of the EPRI PEAC recommendations. These combined efforts have eliminated the impact of voltage sags on plastics processing operations at the plants. As a measure of their satisfaction, the customers have now entered into a three-year energy service contract with Allegheny Power. ■

Fred Frank is an electrical engineer at Allegheny Power, an Allegheny Energy Company (*http://www.alleghenypower.com*) in Greensburg, Pennsylvania. He serves as team leader for Allegheny's Power Quality Team.

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industry on its specific power quality challenges and solutions.

Our work with industry organizations has been an important avenue for reaching plastics customers. Our association with PEP—which is now the Polymers Center of Excellence (PCE)—has been extremely valuable. By providing technical support and training for the plastics industry, PCE has a close alliance with our customers and the inside track on their day-to-day challenges. On the national scale, SPI knows the issues of importance to the industry.

While we have made progress in assessing the power quality needs of plastics processors, there are still questions that need to be addressed. For example, can power quality standards be implemented for equipment? What about standards for facilities? And for energy providers?

With this in mind, Duke Power, PCE, and EPRI will host a Power Quality Workshop in November 1999 (see *EPRI R&D Corner* on page 5). On the agenda for this follow up of the 1997 workshop are case study presentations and strategic planning sessions. The workshop will also promote a working partnership among all industry stakeholders. We believe this partnership is the key to resolving the power quality issues now confronting the industry. ■

Jeff Dougherty is a senior engineer in system power quality at Duke Power (*http://www.duke-energy.com*) in Charlotte, North Carolina. He manages the Duke Power initiatives on power quality in the plastics and metals fabrication industries. He also serves on the PCE Industrial Advisory Committee.

Hotline Highlights

Problem: A polypropylene recycling plant located south of Nashville, Tennessee, experienced periodic tripping of one of its two large extrusion lines. The plant recycles discarded plastic containers into plastic pellets that can be reused to make similar products. First, the containers are shredded and mixed with calcium, virgin plastic, and additives. The dry mix is then augured into the extruders, where friction and pressure heat the mix and form a spaghetti-like material as it flows through the die. From there the material is cut into the plastic pellets and sold for reuse.

Initially, plant engineers suspected the cause of the trips to be voltage unbalance or controller malfunction. They noted that the ac motor-driven extruder would trip only when a nearby 400-hp dc drive powering the other extrusion line was heavily loaded. Their temporary solution was to reduce loading, which diminished production throughput. While there were not significant production losses or much clean up involved when the ac motor would trip, the engineers were concerned that the trips might be signaling a more serious incompatibility between the motor and electric supply that could damage the extruder or reduce its life span.

At this point, they called the Nashville-area service center of Tennessee Valley Authority (TVA). Because the situation involved end-use equipment and a possible problem with the plant equipment, Alex Chomicki of TVA contacted the EPRI PEAC Corporation Hotline. Together, Chomicki, the customer, and engineers from EPRI PEAC investigated the electric service and distribution at the plant.

Using a three-phase power line monitor to evaluate the extruder's ac induction motor, they found only minor unbalances: current measurement was 6%, and voltage was less than 2%. (The ac motor's soft-start protection circuit was set to trip at 35% current unbalance.) They next examined the waveshape of the ac motor current with an oscilloscope in the monitor. Results revealed an unusual depression during one-quarter of the cycle. After some research, the team determined that the change in current waveshape was being misinterpreted by instrumentation as a severe unbalance and was tripping the drive. Measurements at the dc drive terminals indicated normal voltage. However, the drive current in one of the phases had a non-characteristic shape—one hump instead of two—which led to the discovery of a blown fuse on one leg of the drive.

Solution: After calling in the drive manufacturer, the investigators confirmed several problems in the dc drive, including hunting and overspeeding, which may have caused the blown fuse. They also speculated that additional harmonics caused by the missing open fuse might have created a resonance condition that resulted in the unusual waveshape at the ac motor terminals. Once the fuse was replaced, both extruders ran smoothly at all load conditions.

Highlights come from the EPRI PEAC Corporation Hotline. If you have problems you would like addressed, call 1-800-832-PEAC.

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protection relays in the utility distribution system. But, I would ask, who constantly measures even harmonics these days?

And while even harmonics are causing headaches in Belgium, I found our colleagues in neighboring France to be very concerned with another type of harmonic that occurs between the odd and even multiples. These interharmonics were only recently defined for the purposes of measurement and still are without enough practical experience to set any consensus limits.

In the area of voltage sags and ride-through requirements, Swedish scientists told me that in 20% to 50% of the cases they studied, the duration of voltage sags in the 400-kV and 220-kV transmission networks generally was less than 100 milliseconds. Similar to results in the United States, they found that voltage sags originating in radial distribution feeders lasted longer than 100 milliseconds and resulted in a deeper sag in the normal supply.

Spanish researchers drew similar conclusions from measurements on their system. They found that the duration of most voltage sags was between one and five cycles—that is, between 20 and 100 milliseconds at 50 Hz. The Spanish criterion for registering a sag is when the voltage drops 10% to 15% for one cycle. Yet the Swedish data show that industrial customers usually accept voltage sags to a depth near 50% and lasting less than five cycles.

Who is right? For both harmonics and sags, we cannot yet settle on where to draw the line that defines compatibility between the power system and the end user. Today's competitive marketplace brings an expanding and ever-changing variety of electricity sources, end-use equipment, and environmental restrictions. It is crucial that we continually monitor these changes so we can anticipate, and then make, the needed adaptations that best serve our customers.

Marek Samotyj, Manager
EPRI Power Quality Product Line

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(*http://www.socplas.org*); and Manufacturing Extension Partnership, at 800-637-4634 (*http://www.mep.nist.gov*). Placing articles in plastics industry journals and newsletters, making presentations at local and national industry meetings, and offering education and training programs would reach a large portion of the intended audience and would be well received.

With these objectives in mind, the Polymers Center of Excellence (PCE)—along with Duke Power, EPRI, and the Southern Region of SPI—has been working for the past two years to increase the plastics industry's understanding about the causes and effects of poor power quality in their operations. PCE provides technical support and continuing education to plastics processors.

We hope that other advocates from the electric power, equipment manufacturing, and plastics processing industries will step forward to help boost the productivity of the plastics manufacturing sector. It's in the best interests of all concerned. ■

Bob van Brederode is executive director of the Polymers Center of Excellence (*http://www.polymers-center.org*) in Charlotte, North Carolina. He is past president of the Carolinas Section of the Society of Plastics Engineers. PCE was recently formed from the Polymers Extension Program, a part of the industrial extension support provided by the State of North Carolina to its manufacturing industry.

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